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Makiuchi

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(54) **TOUCH PANEL**

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G06F 3/045 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 3/045*** (2013.01); *G06F 2203/04104* (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/045; G06F 2203/04104; G06F 3/0416
See application file for complete search history.

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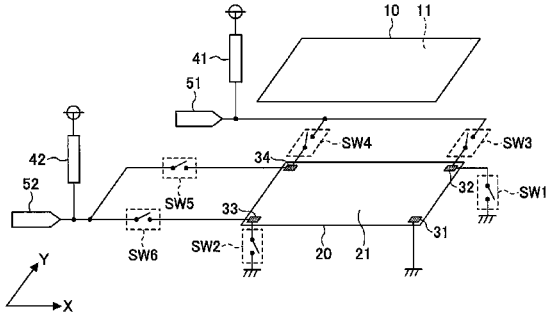
(74) *Attorney, Agent, or Firm* — IPUSA, PLLC

(57) **ABSTRACT**

A touch panel includes an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon, a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon, a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate, a first potential detecting unit configured to detect a potential of the second power feeding terminal, a second potential detecting unit configured to detect a potential of the fourth power feeding terminal, and a third potential detecting unit configured to detect a potential of the third power feeding terminal.

6 Claims, 7 Drawing Sheets



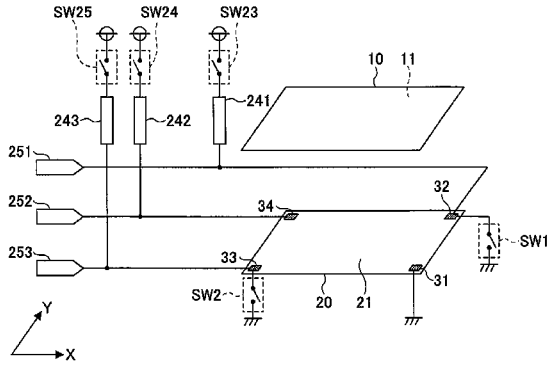


FIG.1

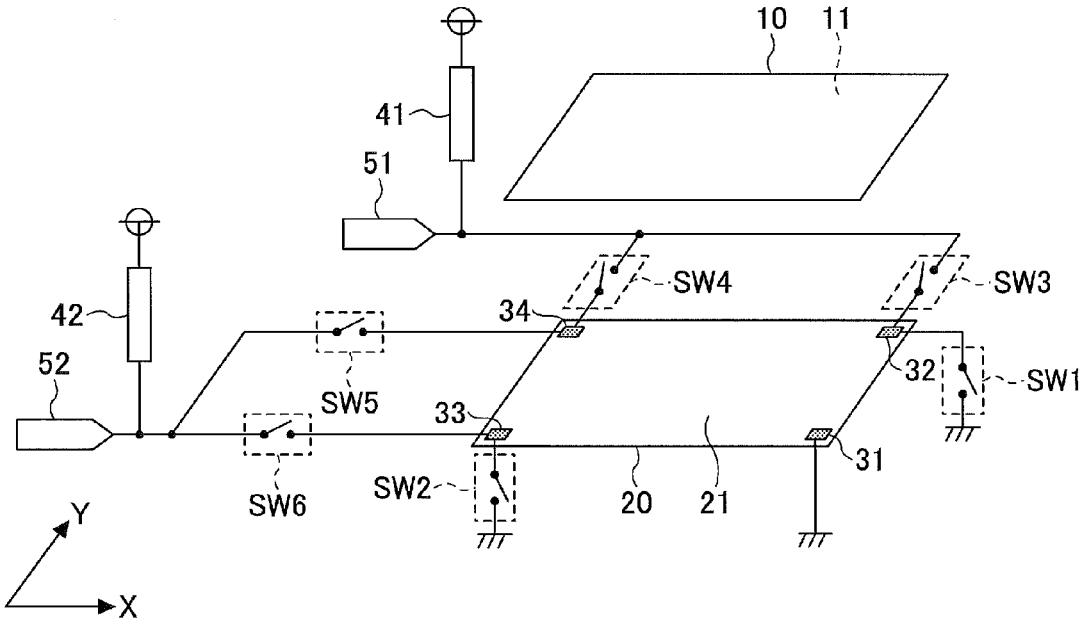

10
11
41
51
42
52
SW4
SW3
34
SW5
32
SW1
33
31
SW6
SW2
20
21
Y
X

FIG.2

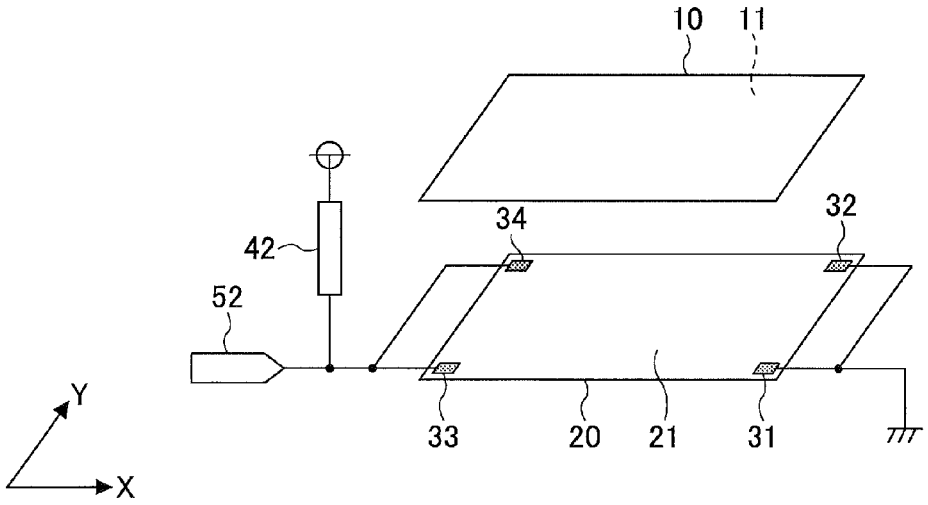

10
11
34
32
42
52
33
20
21
31
Y
X

FIG.3

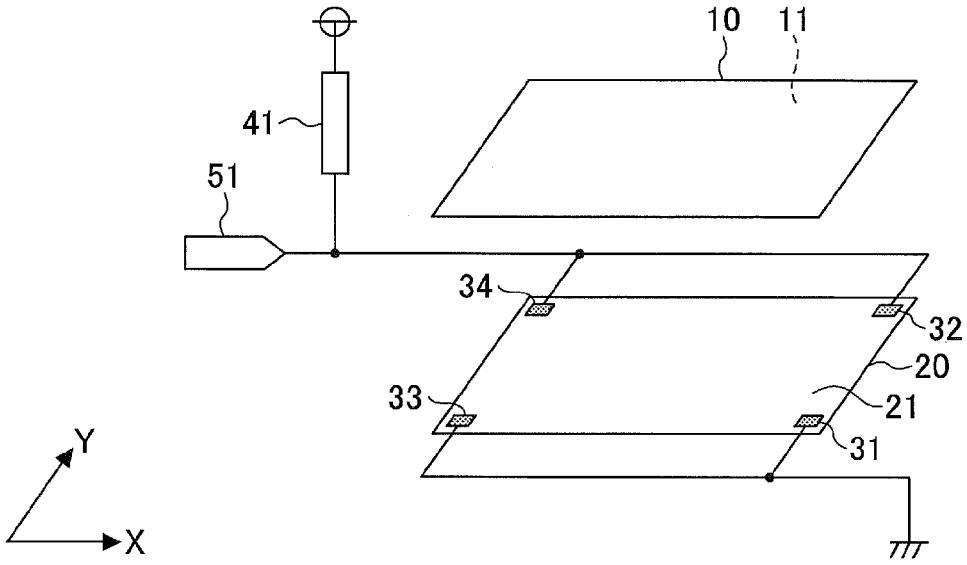

10
11
41
51
34
32
20
33
21
31
Y
X

FIG.4

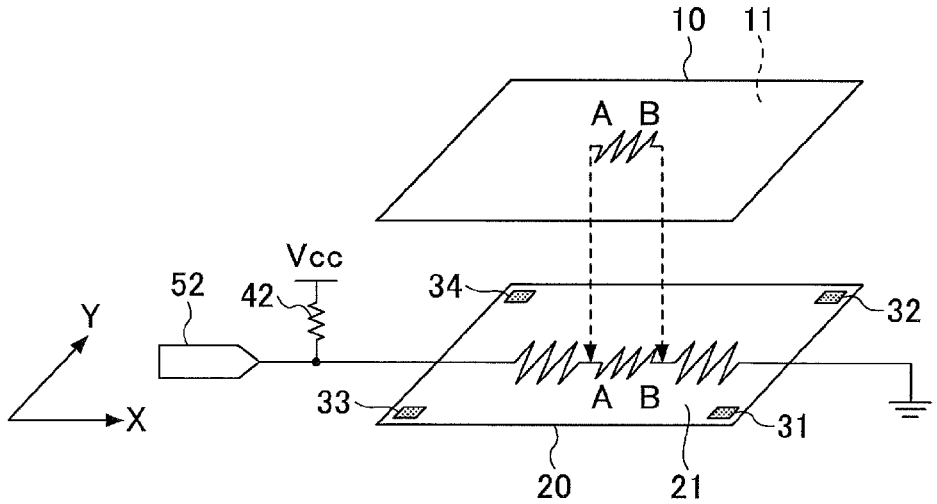

10
11
A
B
Vcc
52
42
34
32
Y
A
B
33
31
X
20
21

FIG.5

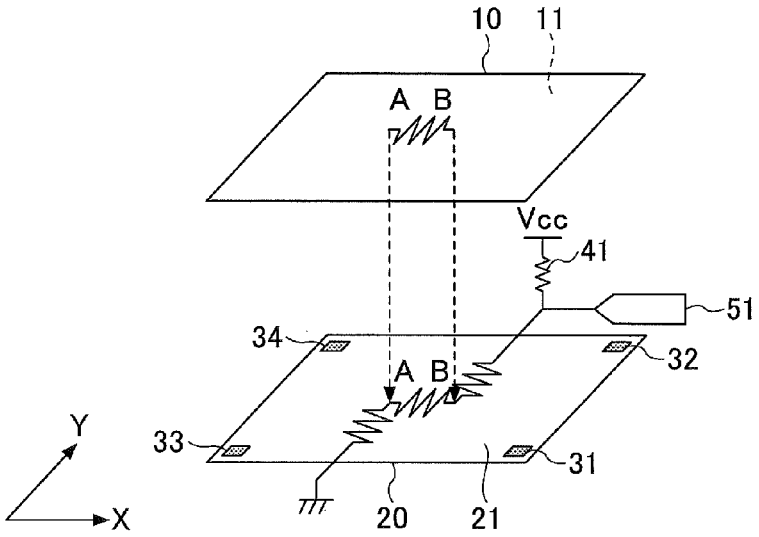

10
11
A
B
Vcc
41
51
34
32
A
B
33
31
Y
X
20
21

FIG.6

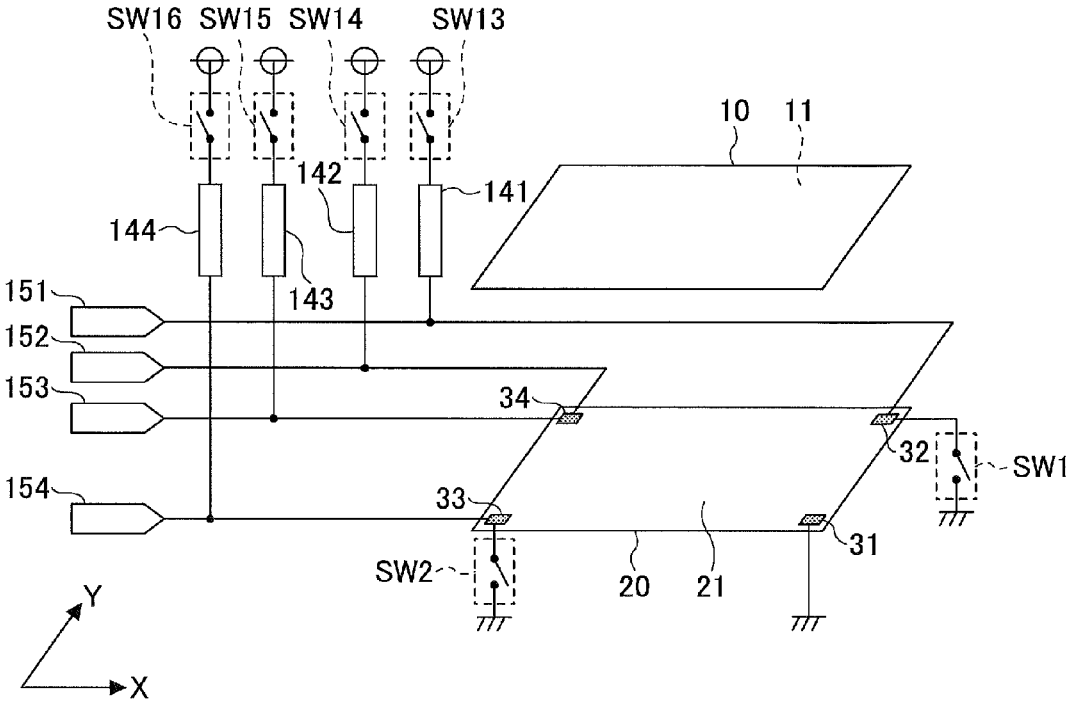

SW16
SW15
SW14
SW13
10
11
142
141
144
143
151
152
153
34
32
SW1
154
33
31
SW2
20
21
Y
X

FIG.7

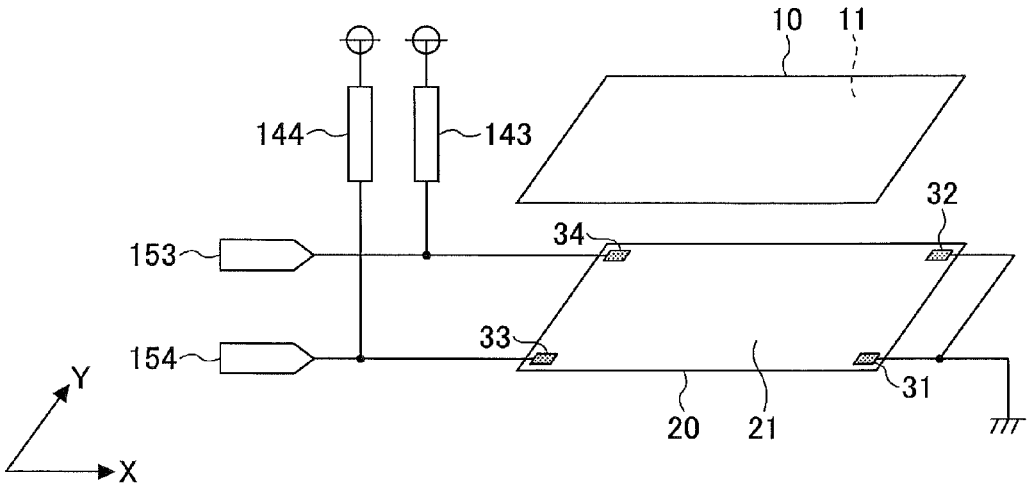

10
11
144
143
32
34
153
33
154
31
20
21
Y
X

FIG.8

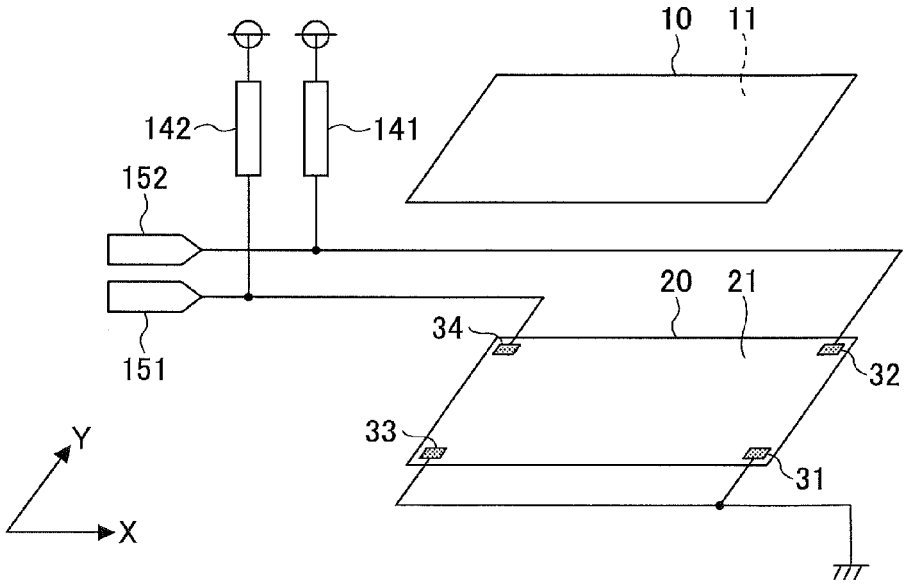

10
11
142
141
152
20
21
34
32
151
33
31
Y
X

FIG.9

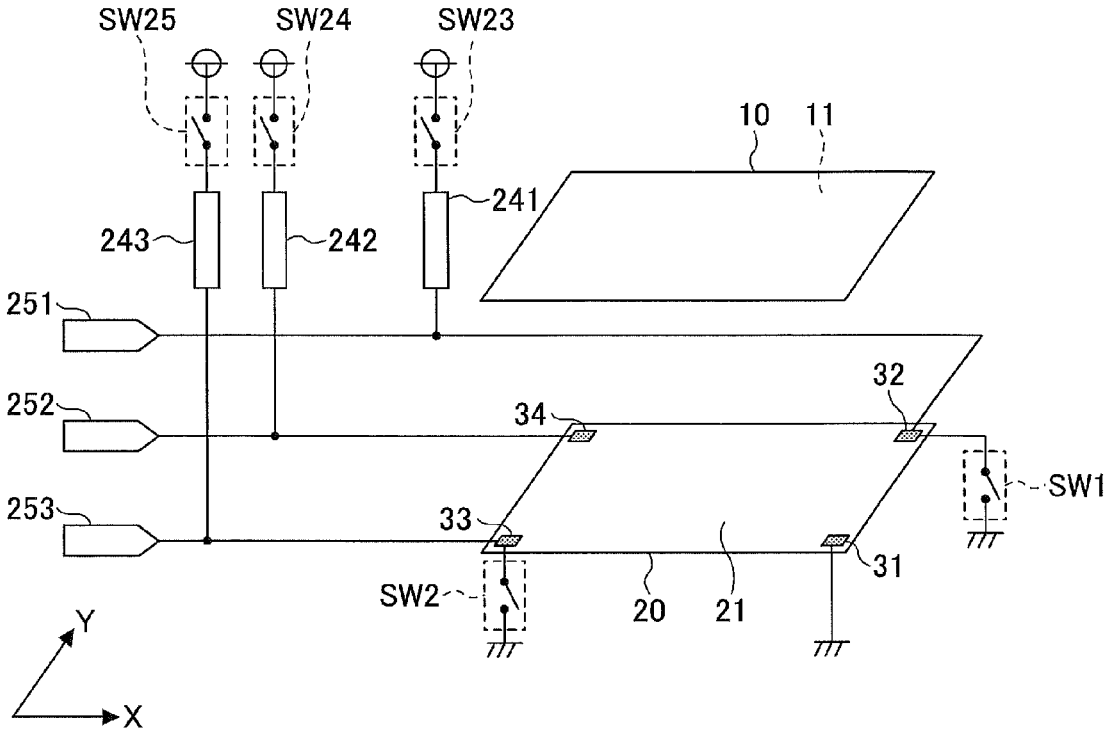

SW25
SW24
SW23
10
11
241
243
242
251
252
253
32
34
33
31
SW1
SW2
20
21
Y
X

FIG.10

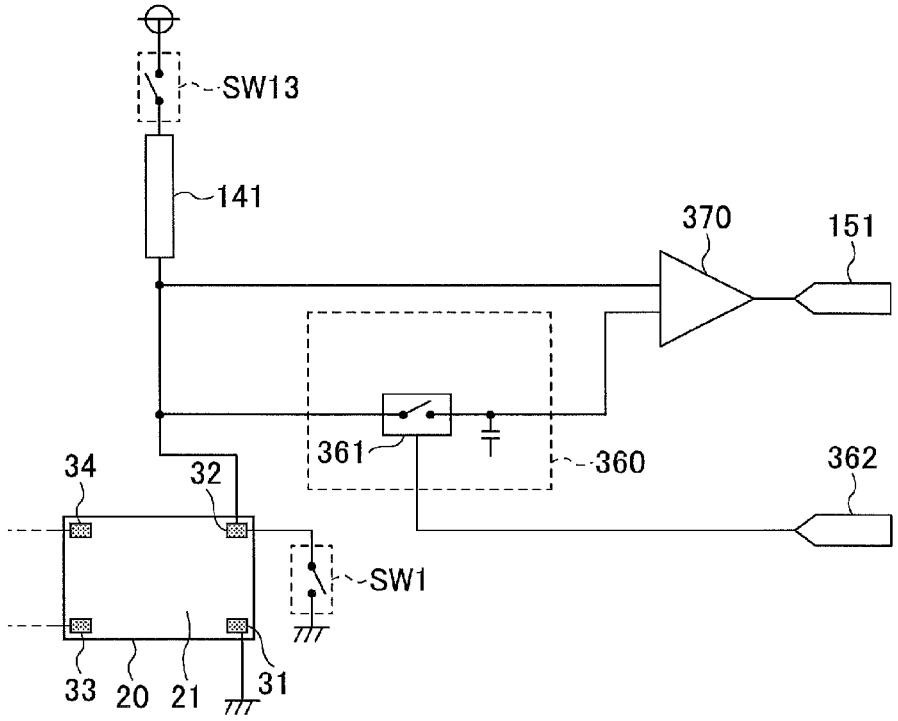

SW13
141
370
151
361
360
362
34
32
SW1
33
20
21
31

FIG.11

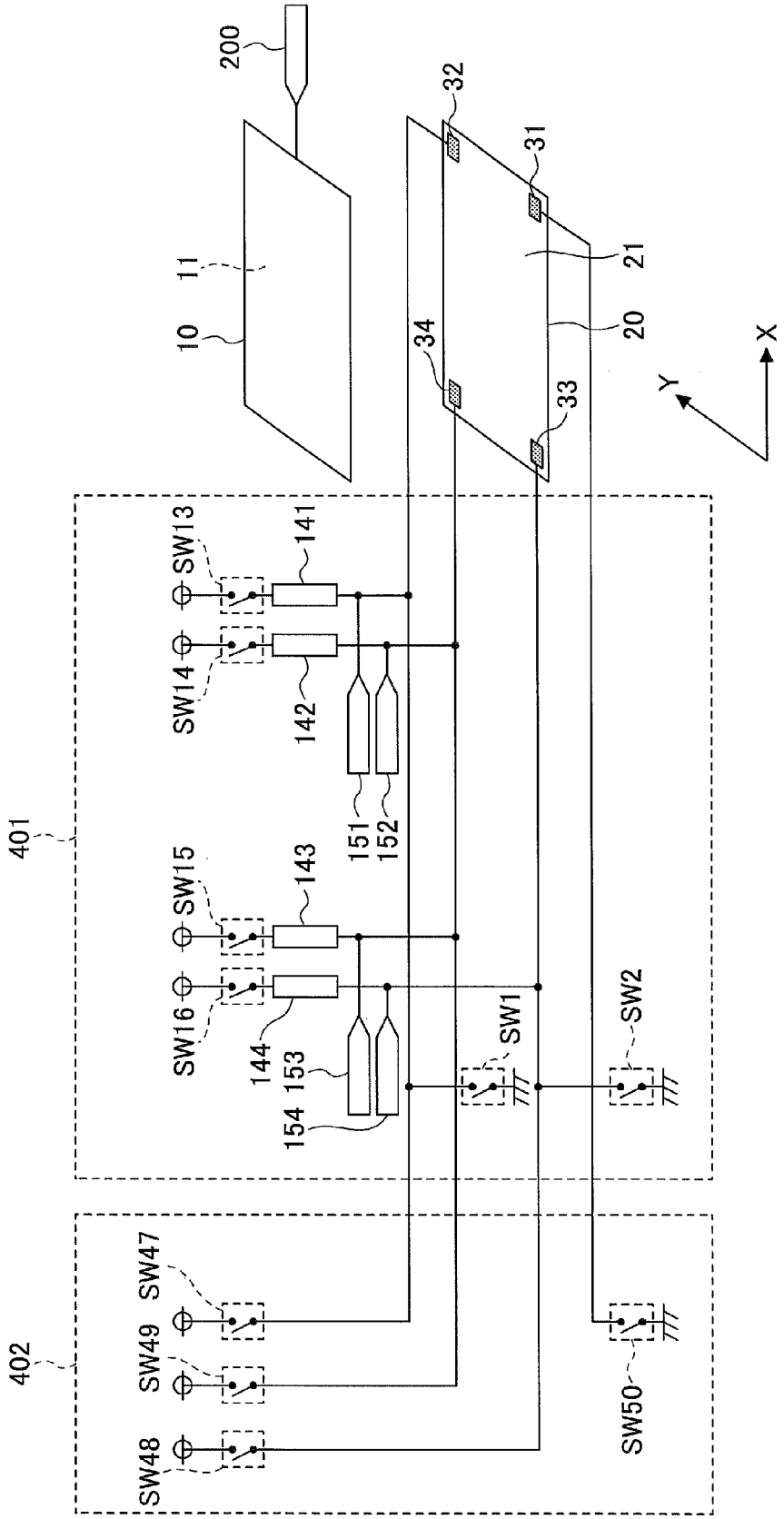

200
32
31
11
21
10
20
34
33
X
Y
401
SW13
141
SW14
142
151
152
SW15
143
SW16
144
153
154
SW1
SW2
402
SW47
SW49
SW48
SW50

FIG.12A

	SW1	SW2	SW13	SW14	SW15	SW16	SW47	SW48	SW49	SW50
X DIRECTION	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
Y DIRECTION	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON

FIG.12B

	SW1	SW2	SW13	SW14	SW15	SW16	SW47	SW48	SW49	SW50
X DIRECTION	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON
Y DIRECTION	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	ON

FIG.12C

	SW1	SW2	SW13	SW14	SW15	SW16	SW47	SW48	SW49	SW50
SAMPLING IN X DIRECTION	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
SAMPLING IN Y DIRECTION	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON

TOUCH PANEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The disclosures herein relate to a touch panel.

2. Description of the Related Art

A touch panel (i.e., touchscreen panel) is an input device that allows input to be directly entered into a display, and is placed in front of the display. Touch panels are widely used in various applications because of their capability of allowing direct inputting based on visual information provided by the display.

A resistive-type touch panel is widely known in the art. The resistive-type touch panel includes an upper electrode substrate and a lower electrode substrate having respective transparent conductive films. These substrates are arranged such that the corresponding transparent conductive films face each other. When pressure is applied to a point on the upper electrode substrate, the transparent conductive films are brought into contact with each other, thereby allowing the position of the pressed point to be detected.

The resistive-type touch panel is classified into a four-wire-type and a five-wire-type. In the four-wire-type, X-axis electrodes are disposed on one of the upper electrode substrate and the lower electrode substrate, and Y-axis electrodes are disposed on the other substrate (see Patent Document 1, for example). In the five-wire-type, X-axis electrodes and Y-axis electrodes are both disposed on the lower electrode substrate while the upper electrode substrate serves as a probe for detecting voltage (see Patent Document 2, for example).

The four-wire-type touch panels include those which allow multiple points of contact to be detected (see Patent Document 4, for example).

There is no five-wire-type touch panel that allows multiple points of contact to be readily detected.

Accordingly, it may be desirable to provide a five-wire-type touch panel that allows multiple points of contact to be readily detected.

[Patent Document 1] Japanese Laid-open Patent Publication No. 2004-272722

[Patent Document 2] Japanese Laid-open Patent Publication No. 2008-293129

[Patent Document 3] Japanese Laid-open Patent Publication No. H11-353101

[Patent Document 4] Japanese Laid-open Patent Publication No. 2009-176114

[Patent Document 5] Japanese Laid-open Patent Publication No. 2012-230504

[Patent Document 6] Japanese Laid-open Patent Publication No. 2012-141941

[Patent Document 7] Japanese National Publication of International Patent Application No. 2005-505065

[Patent Document 8] Japanese National Publication of International Patent Application No. 2011-502314

SUMMARY OF THE INVENTION

According to an embodiment, a touch panel includes an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon, a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon, a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate, a first switch situated between the second power feeding terminal and a ground potential, a second switch situated between the third power feeding terminal and the ground potential, a first resistor and a third switch that are series-connected between the second power feeding terminal and a power supply potential, a first potential detecting unit configured to detect a potential of the second power feeding terminal, a second resistor and a fourth switch that are series-connected between the fourth power feeding terminal and the power supply potential, a second potential detecting unit configured to detect a potential of the fourth power feeding terminal, a third resistor and a fifth switch that are series-connected between the third power feeding terminal and the power supply potential, and a third potential detecting unit configured to detect a potential of the third power feeding terminal.

According to an embodiment, a touch panel includes an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon, a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon, a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate, a first switch situated between the second power feeding terminal and a ground potential, a second switch situated between the third power feeding terminal and the ground potential, a third switch having a first terminal thereof coupled to the second power feeding terminal, a fourth switch having a first terminal thereof coupled to the fourth power feeding terminal, a first resistor having a first end thereof coupled to a second terminal of the third switch and to a second terminal of the fourth switch, a first potential detecting unit configured to detect a potential at a point between the first end of the first resistor and both the second terminal of the third switch and the second terminal of the fourth switch, a fifth switch having a first terminal thereof coupled to the fourth power feeding terminal, a sixth switch having a first terminal thereof coupled to the third power feeding terminal, a second resistor having a first end thereof coupled to a second terminal of the fifth switch and to a second terminal of the sixth switch, and a second potential detecting unit configured to detect a potential at a point between the first end of the second resistor and both the second terminal of the fifth switch and the second terminal of the sixth switch, wherein a second terminal of the first resistor and a second terminal of the second resistor are coupled to a power supply potential.

According to an embodiment, a touch panel includes an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon, a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon, a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate, a first potential detecting unit configured to detect at least one of a potential of the third power feeding terminal and a potential of the fourth power feeding terminal when the third and fourth power feeding terminals are coupled to a first potential, and the first and second power feeding terminals are coupled to a second potential, a second potential detecting unit configured to detect at least one of a potential of the second power feeding terminal and a potential of the fourth power feeding terminal when the second and fourth power feeding terminals are coupled to the first potential, and the first and third power

feeding terminals are coupled to the second potential, and a third potential detecting unit configured to detect a potential of the upper conductive film.

According to at least one embodiment, a five-wire-type touch panel is provided that allows multiple points of contact to be readily detected.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and further features of the present invention will be apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. **1** is a drawing illustrating the structure of a touch panel of a first embodiment;

FIG. **2** is an illustrative drawing of the touch panel of the first embodiment;

FIG. **3** is an illustrative drawing of the touch panel of the first embodiment;

FIG. **4** is an illustrative drawing of the touch panel of the first embodiment;

FIG. **5** is an illustrative drawing of the touch panel of the first embodiment;

FIG. **6** is a drawing illustrating the structure of a touch panel of a second embodiment;

FIG. **7** is an illustrative drawing of the touch panel of the second embodiment;

FIG. **8** is an illustrative drawing of the touch panel of the second embodiment;

FIG. **9** is a drawing illustrating the structure of a touch panel of a third embodiment;

FIG. **10** is an illustrative drawing of a touch panel of a fourth embodiment;

FIG. **11** is a drawing illustrating the structure of a touch panel of a fifth embodiment; and

FIGS. **12**A through **12**C are illustrative drawings of a method of controlling the touch panel of the fifth embodiment.

DESCRIPTION OF EMBODIMENTS

In the following, embodiments will be described by referring to the accompanying drawings. The same or similar elements are referred to by the same or similar numerals.

First Embodiment

In the following, a description will be given of a touch panel according to a first embodiment. This embodiment is directed to a five-wire-type touch panel that is capable of detecting two contact points.

With reference to FIG. **1**, a description will be given of a touch panel according to the present embodiment. The touch panel of the present embodiment includes an upper electrode substrate **10** and a lower electrode substrate **20**. The upper electrode substrate **10** is a rectangular substrate made of glass or transparent resin material that has a transparent conductive film **11** made of ITO (Indium Tin Oxide) or the like formed thereon to serve as an upper conductive film. The lower electrode substrate **20** is a rectangular substrate made of glass or transparent resin material that has a transparent conductive film **21** made of ITO (Indium Tin Oxide) or the like formed thereon to serve as a lower conductive film. The upper electrode substrate **10** and the lower electrode substrate **20** are placed such that the transparent conductive film **11** and the transparent conductive film **21** face each other.

The four corners of the lower electrode substrate **20** have a first power feeding terminal **31**, a second power feeding terminal **32**, a third power feeding terminal **33**, and a fourth power feeding terminal **34** formed on the transparent conductive film **21**. In the present embodiment, the straight line connecting between the first power feeding terminal **31** and the second power feeding terminal **32** and the straight line connecting between the third power feeding terminal **33** and the fourth power feeding terminal **34** are both parallel to the Y axis. Further, the straight line connecting between the first power feeding terminal **31** and the third power feeding terminal **33** and the straight line connecting between the second power feeding terminal **32** and the fourth power feeding terminal **34** are both parallel to the X axis.

The first power feeding terminal **31** is coupled to the ground, and receives a voltage of 0 V. The second power feeding terminal **32** is coupled to a first terminal of a first switch SW**1**, and a second terminal of the first switch SW**1** is coupled to the ground potential. The third power feeding terminal **33** is coupled to a first terminal of a second switch SW**2**, and a second terminal of the second switch SW**2** is coupled to the ground potential.

The second power feeding terminal **32** is coupled to the power supply potential through a third switch SW**3** and a first resistor **41** that are series-connected. The third power feeding terminal **33** is coupled to the power supply potential through a sixth switch SW**6** and a second resistor **42** that are series-connected. The fourth power feeding terminal **34** is coupled to the power supply potential through a fourth switch SW**4** and the first resistor **41** that are series-connected. The fourth power feeding terminal **34** is further coupled to the power supply potential through a fifth switch SW**5** and the second resistor **42** that are series-connected.

Namely, the second power feeding terminal **32** is coupled to a first terminal of the third switch SW**3**, and the fourth power feeding terminal **34** is coupled to a first terminal of the fourth switch SW**4**, with a second terminal of the third switch SW**3** and a second terminal of the fourth switch SW**4** being coupled to each other. Further, the second terminal of the third switch SW**3** and the second terminal of the fourth switch SW**4** are coupled to one end of the first resistor **41**, and the other end of the first resistor **41** is coupled to the power supply potential. Moreover, a first potential detecting unit **51** is coupled to a connection point between the second terminal of the third switch SW**3**, the second terminal of the fourth switch SW**4**, and the above-noted one end of the first resistor **41**.

The third power feeding terminal **33** is coupled to a first terminal of the sixth switch SW**6**, and the fourth power feeding terminal **34** is coupled to a first terminal of the fifth switch SW**5**, with a second terminal of the sixth switch SW**6** and a second terminal of the fifth switch SW**5** being coupled to each other. Further, the second terminal of the sixth switch SW**6** and the second terminal of the fifth switch SW**5** are coupled to one end of the second resistor **42**, and the other end of the second resistor **42** is coupled to the power supply potential. Moreover, a second potential detecting unit **52** is coupled to a connection point between the second terminal of the sixth switch SW**6**, the second terminal of the fifth switch SW**5**, and the above-noted one end of the second resistor **42**.

In order to perform a measurement in the X-axis direction in the touch panel of the present embodiment, the first switch SW**1** is closed, and the second switch SW**2** is open, with the third switch SW**3** and the fourth switch SW**4** being open, and the fifth switch SW**5** and the sixth switch SW**6** being closed. With this arrangement, as illustrated in FIG. **2**, the first power feeding terminal **31** and the second power feeding terminal **32** are coupled to the ground, and the third power feeding termi-

nal **33** and the fourth power feeding terminal **34** are coupled to the power supply potential through the second resistor **42**. As a result, the transparent conductive film **21** of the lower electrode substrate **20** has a potential gradient in the X-axis direction.

In order to perform a measurement in the Y-axis direction in the touch panel of the present embodiment, the first switch SW**1** is open, and the second switch SW**2** is closed, with the third switch SW**3** and the fourth switch SW**4** being closed, and the fifth switch SW**5** and the sixth switch SW**6** being open. With this arrangement, as illustrated in FIG. **3**, the first power feeding terminal **31** and the third power feeding terminal **33** are coupled to the ground, and the second power feeding terminal **32** and the fourth power feeding terminal **34** are coupled to the power supply potential through the first resistor **41**. As a result, the transparent conductive film **21** of the lower electrode substrate **20** has a potential gradient in the Y-axis direction.

In the touch panel of the present embodiment, as illustrated in FIG. **2**, a potential gradient is generated in the X-axis direction, and the second potential detecting unit **52** is used to detect a voltage divided by the second resistor **42** and the resistance of the touch panel. With the resistance of the second resistor **42** being known, the resistance of the touch panel is derived from the detected divided voltage. The resistance of the touch panel is the resistance of the transparent conductive film **21** in the X-axis direction between the pair of the third power feeding terminal **33** and the fourth power feeding terminal **34** and the pair of the first power feeding terminal **31** and the second power feeding terminal **32** when there is no touch or when there is a single point of touch. It may be noted that in the case of pressure being applied at a single point on the upper electrode substrate **10**, the transparent conductive film **11** and the transparent conductive film **21** come in contact with each other only at this single point of touch. The resistance of the touch panel as measured by the above-noted configuration is not affected by the presence of such a single point touch.

In the case of pressure being applied at two points on the upper electrode substrate **10**, on the other hand, the transparent conductive film **11** and the transparent conductive film **21** come in contact with each other at these two points of touch, between which a portion of the transparent conductive film **11** and a portion of the transparent conductive film **21** are parallel-connected to form parallel-connected resistances. The resistance of the touch panel as measured by the above-noted configuration thus involves such parallel-connected resistances, and is responsive to the distance between the two points of touch.

Further, as illustrated in FIG. **3**, a potential gradient is generated in the Y-axis direction, and the first potential detecting unit **51** is used to detect a voltage divided by the first resistor **41** and the resistance of the touch panel. With the resistance of the first resistor **41** being known, the resistance of the touch panel is derived from the detected divided voltage. The resistance of the touch panel is the resistance of the transparent conductive film **21** in the Y-axis direction between the pair of the second power feeding terminal **32** and the fourth power feeding terminal **34** and the pair of the first power feeding terminal **31** and the third power feeding terminal **33** when there is no touch or when there is a single point of touch. The resistance of the touch panel as measured by the above-noted configuration is not affected by the presence of a single point touch.

In the case of pressure being applied at two points on the upper electrode substrate **10**, on the other hand, the transparent conductive film **11** and the transparent conductive film **21** come in contact with each other at these two points of touch, between which a portion of the transparent conductive film **11** and a portion of the transparent conductive film **21** are parallel-connected to form parallel-connected resistances. The resistance of the touch panel as measured by the above-noted configuration thus involves such parallel-connected resistances, and is responsive to the distance between the two points of touch.

With the above-described arrangement, the distance as well as a change in the distance between two points of contact such as points A and B illustrated in FIG. **4** and FIG. **5**, for example, are detectable based on the resistance between the point A and the point B. This arrangement thus enables the detection of a multi-touch operation. FIG. **4** illustrates a case in which the second potential detecting unit **52** detects a potential when a potential gradient in the X-axis direction is generated as illustrated in FIG. **2**. FIG. **5** illustrates a case in which the first potential detecting unit **51** detects a potential when a potential gradient in the Y-axis direction is generated as illustrated in FIG. **3**.

Second Embodiment

In the following, a description will be given of a touch panel according to a second embodiment. This embodiment is directed to a five-wire-type touch panel which includes the upper electrode substrate **10** and the lower electrode substrate **20**, and which enables the detection of positions of two contact points when there are two points of touch on the touch panel. With this arrangement, multi-touch gestures can be identified when there are two points of touch on the touch panel.

With reference to FIG. **6**, a description will be given of a touch panel according to the present embodiment. In the touch panel of the present embodiment, the upper electrode substrate **10** is a rectangular substrate made of glass or transparent resin material that has a transparent conductive film **11** made of ITO or the like formed thereon to serve as an upper conductive film. The lower electrode substrate **20** is a rectangular substrate made of glass or transparent resin material that has a transparent conductive film **21** made of ITO (Indium Tin Oxide) or the like formed thereon to serve as a lower conductive film. The upper electrode substrate **10** and the lower electrode substrate **20** are placed such that the transparent conductive film **11** and the transparent conductive film **21** face each other.

The four corners of the lower electrode substrate **20** have a first power feeding terminal **31**, a second power feeding terminal **32**, a third power feeding terminal **33**, and a fourth power feeding terminal **34** formed on the transparent conductive film **21**. In the present embodiment, the straight line connecting between the first power feeding terminal **31** and the second power feeding terminal **32** and the straight line connecting between the third power feeding terminal **33** and the fourth power feeding terminal **34** are both parallel to the Y axis. Further, the straight line connecting between the first power feeding terminal **31** and the third power feeding terminal **33** and the straight line connecting between the second power feeding terminal **32** and the fourth power feeding terminal **34** are both parallel to the X axis.

The first power feeding terminal **31** is coupled to the ground, and receives a voltage of 0 V. The second power feeding terminal **32** is coupled to a first terminal of a first switch SW**1**, and a second terminal of the first switch SW**1** is coupled to the ground potential. The third power feeding terminal **33** is coupled to a first terminal of a second switch

SW2, and a second terminal of the second switch SW2 is coupled to the ground potential.

The second power feeding terminal **32** is coupled to the power supply potential through a first resistor **141** and a third switch SW13 that are series-connected. The third power feeding terminal **33** is coupled to the power supply potential through a fourth resistor **144** and a sixth switch SW16 that are series-connected. The fourth power feeding terminal **34** is coupled to the power supply potential through a second resistor **142** and a fourth switch SW14 that are series-connected. The fourth power feeding terminal **34** is also coupled to the power supply potential through a third resistor **143** and a fifth switch SW15 that are series-connected.

Namely, the second power feeding terminal **32** is coupled to one end of the first resistor **141**, and the other end of the first resistor **141** is coupled to a first terminal of the third switch SW13, with a second terminal of the third switch SW13 being coupled to the power supply potential. Further, a connection point between the second power feeding terminal **32** and the above-noted one end of the first resistor **141** is coupled to a first potential detecting unit **151**. With this arrangement, the first potential detecting unit **151** detects the potential of the second power feeding terminal **32**.

Moreover, the third power feeding terminal **33** is coupled to one end of the fourth resistor **144**, and the other end of the fourth resistor **144** is coupled to a first terminal of the sixth switch SW16, with a second terminal of the sixth switch SW16 being coupled to the power supply potential. Further, a connection point between the third power feeding terminal **33** and the above-noted one end of the fourth resistor **144** is coupled to a fourth potential detecting unit **154**. With this arrangement, the fourth potential detecting unit **154** detects the potential of the third power feeding terminal **33**.

Moreover, the fourth power feeding terminal **34** is coupled to one end of the second resistor **142**, and the other end of the second resistor **142** is coupled to a first terminal of the fourth switch SW14, with a second terminal of the fourth switch SW14 being coupled to the power supply potential. Further, a connection point between the fourth power feeding terminal **34** and the above-noted one end of the second resistor **142** is coupled to a second potential detecting unit **152**. With this arrangement, the second potential detecting unit **152** detects the potential of the fourth power feeding terminal **34**.

Moreover, the fourth power feeding terminal **34** is coupled to one end of the third resistor **143**, and the other end of the third resistor **143** is coupled to a first terminal of the fifth switch SW15, with a second terminal of the fifth switch SW15 being coupled to the power supply potential. Further, a connection point between the fourth power feeding terminal **34** and the above-noted one end of the third resistor **143** is coupled to a third potential detecting unit **153**. With this arrangement, the third potential detecting unit **153** detects the potential of the fourth power feeding terminal **34**.

In order to perform a measurement in the X-axis direction in the present embodiment, the first switch SW1 is closed, and the second switch SW2 is open, with the third switch SW13 and the fourth switch SW14 being open, and the fifth switch SW15 and the sixth switch SW16 being closed. With this arrangement, as illustrated in FIG. **7**, the first power feeding terminal **31** and the second power feeding terminal **32** are coupled to the ground, with the third power feeding terminal **33** being coupled to the power supply potential through the fourth resistor **144**, and the fourth power feeding terminal **34** being coupled to the power supply potential through the third resistor **143**. As a result, the transparent conductive film **21** of the lower electrode substrate **20** has a potential gradient in the X-axis direction. In this state, the third potential detecting unit **153** and the fourth potential detecting unit **154** perform potential detections.

In order to perform a measurement in the Y-axis direction, the first switch SW1 is open, and the second switch SW2 is closed, with the third switch SW13 and the fourth switch SW14 being closed, and the fifth switch SW15 and the sixth switch SW16 being open. With this arrangement, as illustrated in FIG. **8**, the first power feeding terminal **31** and the third power feeding terminal **33** are coupled to the ground, with the second power feeding terminal **32** being coupled to the power supply potential through the first resistor **141**, and the fourth power feeding terminal **34** being coupled to the power supply potential through the second resistor **142**. As a result, the transparent conductive film **21** of the lower electrode substrate **20** has a potential gradient in the Y-axis direction. In this state, the first potential detecting unit **151** and the second potential detecting unit **152** perform potential detections.

Subsequently, the coordinate positions of two points of touch on the touch panel are calculated based on the respective potentials detected by the third potential detecting unit **153** and the fourth potential detecting unit **154** and the respective potentials detected by the first potential detecting unit **151** and the second potential detecting unit **152**. With this arrangement, multi-touch gestures can be identified when there are two points of touch.

In the present embodiment, the first resistor **141** may have a resistance equal to the resistance between the second power feeding terminal **32** and the first power feeding terminal **31**, and the second resistor **142** may have a resistance equal to the resistance between the fourth power feeding terminal **34** and the third power feeding terminal **33**. Further, the third resistor **143** may have a resistance equal to the resistance between the fourth power feeding terminal **34** and the second power feeding terminal **32**, and the fourth resistor **144** may have a resistance equal to the resistance between the third power feeding terminal **33** and the first power feeding terminal **31**.

Third Embodiment

In the following, a description will be given of a touch panel according to a third embodiment. The touch panel of this embodiment is directed to a configuration in which the numbers of resistors, potential detecting units, and switches are reduced compared with the touch panel of the second embodiment. The present embodiment thus provides a touch panel having the same or similar functions as the touch panel of the second embodiment at a lower cost.

With reference to FIG. **9**, a description will be given of the touch panel according to the present embodiment. In the touch panel of the present embodiment, the first power feeding terminal **31** is coupled to the ground, and receives a voltage of 0 V. The second power feeding terminal **32** is coupled to a first terminal of a first switch SW1, and a second terminal of the first switch SW1 is coupled to the ground potential. The third power feeding terminal **33** is coupled to a first terminal of a second switch SW2, and a second terminal of the second switch SW2 is coupled to the ground potential.

The second power feeding terminal **32** is coupled to the power supply potential through a first resistor **241** and a third switch SW23 that are series-connected. The third power feeding terminal **33** is also coupled to the power supply potential through a third resistor **243** and a fifth switch SW25 that are series-connected. The fourth power feeding terminal **34** is coupled to the power supply potential through a second resistor **242** and a fourth switch SW24 that are series-connected.

Namely, the second power feeding terminal **32** is coupled to one end of the first resistor **241**, and the other end of the first resistor **241** is coupled to a first terminal of the third switch SW**23**, with a second terminal of the third switch SW**23** being coupled to the power supply potential. Further, a connection point between the second power feeding terminal **32** and the above-noted one end of the first resistor **241** is coupled to a first potential detecting unit **251**. With this arrangement, the first potential detecting unit **251** detects the potential of the second power feeding terminal **32**.

Moreover, the third power feeding terminal **33** is coupled to one end of the third resistor **243**, and the other end of the third resistor **243** is coupled to a first terminal of the fifth switch SW**25**, with a second terminal of the fifth switch SW**25** being coupled to the power supply potential. Further, a connection point between the third power feeding terminal **33** and the above-noted one end of the third resistor **243** is coupled to a third potential detecting unit **253**. With this arrangement, the third potential detecting unit **253** detects the potential of the third power feeding terminal **33**.

Moreover, the fourth power feeding terminal **34** is coupled to one end of the second resistor **242**, and the other end of the second resistor **242** is coupled to a first terminal of the fourth switch SW**24**, with a second terminal of the fourth switch SW**24** being coupled to the power supply potential. Further, a connection point between the fourth power feeding terminal **34** and the above-noted one end of the second resistor **242** is coupled to a second potential detecting unit **252**. With this arrangement, the second potential detecting unit **252** detects the potential of the fourth power feeding terminal **34**.

In other words, the present embodiment uses the second potential detecting unit **252** that serves the functions of both the second potential detecting unit **152** and the third potential detecting unit **153** of the second embodiment. Further, the second resistor **242** serves the functions of both the second resistor **142** and the third resistor **143** of the second embodiment. The fourth switch SW**24** serves the functions of both the fourth switch SW**14** and the fifth switch SW**15** of the second embodiment.

In the present embodiment, the first resistor **241** may have a resistance equal to the resistance between the second power feeding terminal **32** and the first power feeding terminal **31**, and the second resistor **242** may have a resistance equal to the resistance between the fourth power feeding terminal **34** and the third power feeding terminal **33**. Further, the third resistor **243** may have a resistance equal to the resistance between the fourth power feeding terminal **34** and the second power feeding terminal **32**, or may have a resistance equal to the resistance between the third power feeding terminal **33** and the first power feeding terminal **31**.

Further, the first resistor **241** of the present embodiment corresponds to the first resistor **141** of the second embodiment, and the third resistor **243** corresponds to the fourth resistor **144** of the second embodiment. Further, the third switch SW**23** of the present embodiment corresponds to the third switch SW**13** of the second embodiment, and the fifth switch SW**25** corresponds to the sixth switch SW**16** of the second embodiment. Further, the first potential detecting unit **251** of the present embodiment corresponds to the first potential detecting unit **151** of the second embodiment, and the third potential detecting unit **253** corresponds to the fourth potential detecting unit **154** of the second embodiment.

In the present embodiment, the second resistor **242** serves the functions of both the second resistor **142** and the third resistor **143** of the touch panel of the second embodiment. The second potential detecting unit **252** serves the functions of both the second potential detecting unit **152** and the third potential detecting unit **153** of the touch panel of the second embodiment. Further, the fourth switch SW**24** serves the functions of both the fourth switch SW**14** and the fifth switch SW**15** of the touch panel of the second embodiment.

Configurations other than those described above are the same as or similar to those of the second embodiment.

Fourth Embodiment

In a typical five-wire-type touch panel, a low resistance pattern is formed on the perimeter of the transparent conductive film **21** on the surface thereof facing toward the glass, thereby providing a homogeneous potential distribution. When pressure is applied to the touch panel at two points of touch, the transparent conductive film **11** and the transparent conductive film **21** form parallel-connected resistances whose combined resistance varies in response to the positions of the two points of touch. A change in the combined resistance is detected by an external apparatus by measuring a total resistance including the resistance of the low resistance pattern, so that the magnitude of the detected change is very small and may be smaller than a few ohms. It may be noted that the panel resistance ranges from tens of ohms to hundreds of ohms.

Detecting such a small resistance change as a change in the voltage divided by a potential divider using a fixed resistance may be difficult because the divided voltage may exhibit a change of only a few millivolts at the maximum. Accordingly, there is a need to amplify the divided voltage to a detectable range. When the ratio of the fixed resistance to the panel resistance is 1 to 1, the divided voltage is 2.5 V in the case of a power supply voltage of 5 V. Amplifying such a voltage in a straightforward manner would produce a voltage ranging from tens of voltages to hundreds of voltages, which is difficult to handle. In consideration of this, a voltage of 2.5 V is maintained as a reference voltage, and only a change from this reference voltage is obtained by use of a differential amplifier. Further, a divided voltage of 2.5 V, which varies due to variation in the panel resistance or the fixed resistance, is sampled and held in a given environment by use of a sample and hold circuit.

In the following, a fourth embodiment will be described. The touch panel of this embodiment employs a sample and hold circuit and a differential amplifier situated between a power feeding terminal and a resistor, and further employs a potential detecting unit to measure the output of the differential amplifier. This arrangement enables the accurate detection of the positions of touch as well as the types of gestures by amplifying a detected minute potential change.

With reference to FIG. **10**, a description will be given of the touch panel according to the present embodiment. A description of the present embodiment will be given by referring to an example in which the sample and hold circuit and the differential amplifier are employed in the touch panel of the second embodiment. This is not a limiting example, and the configuration of the present embodiment is also applicable to the touch panels of the first and third embodiments. FIG. **10** illustrates an example in which the sample and hold circuit and the differential amplifier are situated between the first resistor **141** and the second power feeding terminal **32** disposed on the lower electrode substrate **20**. The same or similar configuration is also employed with respect to the path between third power feeding terminal **33** and the fourth resistor **144**, the path between the fourth power feeding terminal **34** and the second resistor **142**, and the path between the fourth power feeding terminal **34** and the third resistor **143**.

In the present embodiment, an input terminal of a sample and hold circuit **360** and one of the input terminals of a differential amplifier **370** are connected to the path between the first resistor **141** and the second power feeding terminal **32** disposed on the lower electrode substrate **20**. The sample and hold circuit **360** includes a sample and hold switch **361**. A sample and hold control unit **362** situated in a controller or the like controls the operation of the sample and hold switch **361**. The sample and hold circuit **360** serves to sample and hold a potential that is observed when there is no touch on the touch panel by a finger or the like. Namely, the sample and hold switch **361** is closed when the touch panel is free of touch by a finger or the like, so that the sample and hold circuit **360** samples a potential as observed at the input terminal thereof in such a state. With this arrangement, the sample and hold circuit **360** samples and holds the potential as observed when the touch panel is free of touch by a finger or the like. Subsequently, the sample and hold switch **361** is opened. Operations on the touch panel are performed in the state in which the sample and hold switch **361** is open. In this state, the output terminal of the sample and hold circuit **360** provides the potential as observed when there is no touch on the touch panel by a finger or the like.

The output terminal of the sample and hold circuit **360** is connected to one of the input terminals of the differential amplifier **370**, and the other one of the input terminals of the differential amplifier **370** receives a potential observed at a point between the first resistor **141** and the second power feeding terminal **32**. The differential amplifier **370** amplifies a difference between the potentials input into the respective input terminals to produce an amplified difference at the output terminal of the differential amplifier **370**. The signal output from the output terminal of the differential amplifier **370** is supplied to the first potential detecting unit **151**.

In the present embodiment, the signal output from the output terminal of the differential amplifier **370** is a result of amplifying a difference between the potentials input into the respective input terminals of the differential amplifier **370**. Accordingly, the first potential detecting unit **151** detects a signal exhibiting a large change obtained by amplifying a change in the potentials. With this arrangement, the positions of touch points and the types of gestures are detected with improved accuracy even when there are multiple touch points on the touch panel.

In the present embodiment, another sample and hold circuit and another differential amplifier are also situated between the third power feeding terminal **33** and the fourth resistor **144**. The output of this differential amplifier situated between the third power feeding terminal **33** and the fourth resistor **144** is supplied to the fourth potential detecting unit **154**. Further, another sample and hold circuit and another differential amplifier are also situated between the fourth power feeding terminal **34** and the second resistor **142**. The output of this differential amplifier situated between the fourth power feeding terminal **34** and the second resistor **142** is supplied to the second potential detecting unit **152**. Moreover, another sample and hold circuit and another differential amplifier are also situated between the fourth power feeding terminal **34** and the third resistor **143**. The output of this differential amplifier situated between the fourth power feeding terminal **34** and the third resistor **143** is supplied to the third potential detecting unit **153**.

Fifth Embodiment

In the following, a fifth embodiment will be described. A touch panel of the present embodiment is directed to a configuration that has the function to detect a single point of touch on the touch panel of the second embodiment. The present embodiment will be described by referring to the touch panel of the second embodiment as an example. This is not a limiting example, and the present embodiment is also applicable to the touch panels of the first and third embodiments.

The touch panel of the present embodiment includes a multi-touch detecting circuit **401** for detecting two or more points of touch and a single-touch detecting circuit **402** for detecting a single point of touch. The multi-touch detecting circuit **401** of the present embodiment is the same as or similar to the configuration employed in the touch panel of the second embodiment.

The single-touch detecting circuit **402** includes a seventh switch SW**47**, an eighth switch SW**48**, a ninth switch SW**49**, and a tenth switch SW**50**.

Specifically, the second power feeding terminal **32** on the lower electrode substrate **20** is coupled to a first terminal of the seventh switch SW**47**, and a second terminal of the seventh switch SW**47** is coupled to the power supply potential. The first terminal of the first switch SW**1** and the first terminal of the seventh switch SW**47** are coupled to each other. The first switch SW**1** and the seventh switch SW**47** are series-connected between the ground potential and the power supply potential.

The third power feeding terminal **33** is coupled to a first terminal of the eighth switch SW**48**, and a second terminal of the eighth switch SW**48** is coupled to the power supply potential. The first terminal of the second switch SW**2** and the first terminal of the eighth switch SW**48** are coupled to each other. The second switch SW**2** and the eighth switch SW**48** are series-connected between the ground potential and the power supply potential.

The fourth power feeding terminal **34** is coupled to a first terminal of the ninth switch SW**49**, and a second terminal of the ninth switch SW**49** is coupled to the power supply potential. The first power feeding terminal **31** is coupled to a first terminal of the tenth switch SW**50**, and a second terminal of the tenth switch SW**50** is coupled to the ground potential.

A description will be given of position detection in the touch panel of the present embodiment with reference to FIGS. **12**A through **12**C.

A description will first be given of position detection in the case of multi-touch by referring to FIG. **12**A. In this case, the seventh switch SW**47**, the eighth switch SW**48**, and the ninth switch SW**49** are open, and the tenth switch SW**50** is closed.

In order to perform a measurement in the X-axis direction in the this case, the first switch SW**1** is closed, and the second switch SW**2** is open, with the third switch SW**13** and the fourth switch SW**14** being open, and the fifth switch SW**15** and the sixth switch SW**16** being closed.

In order to perform a measurement in the Y-axis direction, the first switch SW**1** is open, and the second switch SW**2** is closed, with the third switch SW**13** and the fourth switch SW**14** being closed, and the fifth switch SW**15** and the sixth switch SW**16** being open.

A description will next be given of the position detection of a single point of touch and the position detection of a midpoint between two points of touch by referring to FIG. **12**B. In this case, the third switch SW**13**, the fourth switch SW**14**, and the fifth switch SW**15**, and the sixth switch SW**16** are open.

In order to perform a measurement in the X-axis direction in the this case, the first switch SW**1** is closed, and the second switch SW**2** is open, with the seventh switch SW**47** being open, the eighth switch SW**48** and the ninth switch SW**49** being closed, and the tenth switch SW**50** being closed. With

the switches being in the above-noted states, the third power feeding terminal **33** and the fourth power feeding terminal **34** are set to the power supply potential, and the first power feeding terminal **31** and the second power feeding terminal **32** are set to the ground potential, so that a potential gradient in the X-axis direction is formed in the transparent conductive film **21**. When pressure is applied to the touch panel, the transparent conductive film **11** comes in contact with the transparent conductive film **21**. A detecting unit **200** connected to the transparent conductive film **11** detects a potential generated by such contact with the transparent conductive film **21** that is responsive to the position(s) of contact in the X-axis direction.

In order to perform a measurement in the Y-axis direction, the first switch SW**1** is open, and the second switch SW**2** is closed, with the seventh switch SW**47** being closed, the eighth switch SW**48** being open, and the ninth switch SW**49** and the tenth switch SW**50** being closed. With the switches being in the above-noted states, the second power feeding terminal **32** and the fourth power feeding terminal **34** are set to the power supply potential, and the first power feeding terminal **31** and the third power feeding terminal **33** are set to the ground potential, so that a potential gradient in the Y-axis direction is formed in the transparent conductive film **21**. When pressure is applied to the touch panel, the transparent conductive film **11** comes in contact with the transparent conductive film **21**. The detecting unit **200** connected to the transparent conductive film **11** detects a potential generated by such contact with the transparent conductive film **21** that is responsive to the position(s) of contact in the Y-axis direction.

A description will further be given of the sampling and holding of a potential when the touch panel of the fourth embodiment is free of touch by a finger or the like by referring to FIG. **12**C. In this case, the switches are set in the same manner as in the case of detecting the positions of multi-touch points. That is, the seventh switch SW**47**, the eighth switch SW**48**, and the ninth switch SW**49** are open, and the tenth switch SW**50** is closed.

In order to perform a sample-and-hold operation in the X-axis direction in the this case, the first switch SW**1** is closed, and the second switch SW**2** is open, with the third switch SW**13** and the fourth switch SW**14** being open, and the fifth switch SW**15** and the sixth switch SW**16** being closed.

In order to perform a sample-and-hold operation in the Y-axis direction, the first switch SW**1** is open, and the second switch SW**2** is closed, with the third switch SW**13** and the fourth switch SW**14** being closed, and the fifth switch SW**15** and the sixth switch SW**16** being, open.

Further, although the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese priority application No. 2014-034476 filed on Feb. 25, 2014, with the Japanese Patent Office, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A touch panel, comprising:

an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon;

a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon;

a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate;

a first switch situated between the second power feeding terminal and a ground potential;

a second switch situated between the third power feeding terminal and the ground potential;

a first resistor and a third switch that are series-connected between the second power feeding terminal and a power supply potential;

a first potential detecting unit configured to detect a potential of the second power feeding terminal;

a second resistor and a fourth switch that are series-connected between the fourth power feeding terminal and the power supply potential;

a second potential detecting unit configured to detect a potential of the fourth power feeding terminal;

a third resistor and a fifth switch that are series-connected between the third power feeding terminal and the power supply potential; and

a third potential detecting unit configured to detect a potential of the third power feeding terminal.

2. The touch panel as claimed in claim **1**, further comprising:

a fourth resistor and a sixth switch that are series-connected between the fourth power feeding terminal and the power supply potential; and

a fourth potential detecting unit configured to detect a potential of the fourth power feeding terminal.

3. The touch panel as claimed in claim **2**, wherein the first resistor, the second resistor, the third resistor, and the fourth resistor all have a same resistance value.

4. The touch panel as claimed in claim **1**, further comprising:

sample and hold circuits; and

differential amplifiers,

wherein any given one of the second power feeding terminal, the third power feeding terminal, and the fourth power feeding terminal is coupled to an input terminal of a corresponding one of the sample and hold circuits and to an input terminal of a corresponding one of the differential amplifiers,

wherein an output terminal of the corresponding one of the sample and hold circuits is coupled to another input terminal of the corresponding one of the differential amplifiers, and

wherein output terminals of the differential amplifiers are coupled to the first potential detecting unit, the second potential detecting unit, and the third potential detecting unit.

5. A touch panel, comprising:

an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon;

a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon;

a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate;

a first switch situated between the second power feeding terminal and a ground potential;

a second switch situated between the third power feeding terminal and the ground potential;

a third switch having a first terminal thereof coupled to the second power feeding terminal;

a fourth switch having a first terminal thereof coupled to the fourth power feeding terminal;

a first resistor having a first end thereof coupled to a second terminal of the third switch and to a second terminal of the fourth switch;

a first potential detecting unit configured to detect a potential at a point between the first end of the first resistor and both the second terminal of the third switch and the second terminal of the fourth switch;

a fifth switch having a first terminal thereof coupled to the fourth power feeding terminal;

a sixth switch having a first terminal thereof coupled to the third power feeding terminal;

a second resistor having a first end thereof coupled to a second terminal of the fifth switch and to a second terminal of the sixth switch; and

a second potential detecting unit configured to detect a potential at a point between the first end of the second resistor and both the second terminal of the fifth switch and the second terminal of the sixth switch,

wherein a second terminal of the first resistor and a second terminal of the second resistor are coupled to a power supply potential.

6. A touch panel, comprising:

an upper electrode substrate having a rectangular shape and having an upper conductive film formed thereon;

a lower electrode substrate having a rectangular shape and having a lower conductive film formed thereon;

a first power feeding terminal, a second power feeding terminal, a third power feeding terminal, and a fourth power feeding terminal disposed on the lower conductive film at four respective corners of the lower electrode substrate;

a first potential detecting unit configured to detect at least one of a potential of the third power feeding terminal and a potential of the fourth power feeding terminal when the third and fourth power feeding terminals are coupled to a first potential, and the first and second power feeding terminals are coupled to a second potential;

a second potential detecting unit configured to detect at least one of a potential of the second power feeding terminal and a potential of the fourth power feeding terminal when the second and fourth power feeding terminals are coupled to the first potential, and the first and third power feeding terminals are coupled to the second potential; and

a third potential detecting unit configured to detect a potential of the upper conductive film.

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